

NPAL Acoustic Coherence And Broadband Full Field Processing

Arthur B. Baggeroer
Department of Ocean Engineering
Massachusetts Institute of Technology
Cambridge, MA 02139
phone: (617) 253 4336 fax: (617) 253 2350 email: abb@arctic.mit.edu

Henrik Schmidt
Department of Ocean Engineering
Massachusetts Institute of Technology
Cambridge, MA 02139
phone: (617) 253-5727 fax: (617) 253 2350 email: henrik@keel.mit.edu
Award#: N00014-98-1-0274
<http://acoustics.mit.edu>

LONG-TERM GOAL

The long-term goal is to determine the horizontal and vertical coherence of discrete noise sources and the number of degrees of freedom to characterize them. These will be used to specify stochastic models for representing these sources which can be used in designing passive sonar array processing algorithms.

OBJECTIVES

Noise fields in most sonar models are characterized nonparametrically wherein a noise coherence matrix for the array of sensors is estimated across frequency. Arrays are now becoming so large that it is difficult to estimate this matrix reliably because of the nonstationarity. In many environments shipping is a dominant part of the noise field and it does not take much source receiver motion to lead to variability and nonstationarity in the noise field. The variability induced by motion is often much larger than that induced by natural processes such as surface or internal waves. An approach to mitigating this problem is to substitute *a priori* models for some components of the noise field such as the strong, directional ones. A model must incorporate spatial coherence to be useful for sonars with large arrays. My objective is to determine robust models for directional noise sources which include the effects of source motion as well as natural ocean processes and to evaluate their utility for sonar array processing algorithms.

APPROACH

The NPAL (North Pacific Acoustic Laboratory) array was deployed in July 1998 off Pt. Sur. It has five vertical arrays, four with an aperture of 650 m and one with a 1300 m aperture.. The arrays record the ATOC source in Kauai every 4 hours for 20 minutes; since the source transmits episodically, most recordings are ambient noise. The sensors are located with an AEL (acoustic element location) system which is important for separating receiver motion effects in coherence analyses. The "pop up" capsule was recently recovered and the data will soon be available for processing. These data will be reviewed for useful sections, *e.g.* adequate signal levels, sensor position information, then the effective rank of the sensor coherence matrix will be determined.

Report Documentation Page				Form Approved OMB No. 0704-0188	
Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.					
1. REPORT DATE 1998		2. REPORT TYPE		3. DATES COVERED 00-00-1998 to 00-00-1998	
4. TITLE AND SUBTITLE NPAL Acoustic Coherence and Broadband Full Field Processing				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Massachusetts Institute of Technology, Department of Ocean Engineering, Cambridge, MA, 02139				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution unlimited					
13. SUPPLEMENTARY NOTES See also ADM002252.					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT Same as Report (SAR)	18. NUMBER OF PAGES 4	19a. NAME OF RESPONSIBLE PERSON
a. REPORT unclassified	b. ABSTRACT unclassified	c. THIS PAGE unclassified			

The effects of internal wave variability upon modal (vertical) coherence and scattering is analyzed using a combination of the NRL RAM parabolic equation code and a GM spectrum for internal waves. This was first advanced by Dozier and Tappert [1] and is similar in some respects to work by Colosi [2]. The RAM code is calibrated so it has very low numerical scattering across modes in a range independent channel. In a range dependent channel with $\frac{1}{2}$ GM perturbances. The modal scattering is analyzed by initializing with single mode and determining how other modes are populated. The coherent component of the field is the adiabatic component which remains in the initial field; however, the component in the initial field consists of both adiabatic and repopulated power. To separate the adiabatic component the scattered energy was stripped by projecting the field upon the local mode at range steps so fine that the effects of repopulated power are second order. The remaining power represents the adiabatic component and coherent part of the vertical field for a directional source.

RESULTS

The first capsule from the NPAL array was just recently recovered, so there are no results on processing these data. It is expected that the first data will be available December 1998. Kathleen Wage, a graduate research assistant, whose thesis work concerns the ATOC data participated on the NPAL deployment cruise.

The approach above was implemented on a sample set of 14 realizations for a $\frac{1}{2}$ GM perturbation. Figure 1 illustrates the scattering of the modes 1, 2, 4, 8 and 16 *versus* range when initialized with a single starter mode at a frequency of 67.5 Hz. The horizontal axis on each plot is range and the vertical is mode number, so at zero range only the starter mode is present. Adjacent modes are rapidly populated with the power in the initial mode down typically by 10 dB at a 2000 km range. The power which includes both the adiabatic and scattered components is indicated in Figure 2. The horizontal axis is frequency and the vertical range. Higher frequencies lead to lower projection levels and hence more scattering. The larger projections *versus range* for mode 16 seems to reverse the trend evident in the lower order modes. It is not clear whether this is from the adiabatic or repopulated component.

The adiabatic, or coherent, component was estimated by stripping the scattered components. This led to following estimates for the decay ($1/e$) range scale, R_{coh} , for the modes:

Mode #	1	2	4	8
$R_{coh} (km)$	1300	700	800	800

Table 1: Adiabatic ranges for long range modal propagation

If one compensates for the lower level of the GM spectrum used, these ranges compare quite well with results when one manipulates the “master equation” for the scattering matrix as formulated by Tappert and Dozier. This suggests that at this frequency and these ranges one must switch to a stochastic distribution for modeling the signal from a directional source. In addition, it indicates that at 4000 km the SNR on the adiabatic component for mode 1, which is often used for tomographic inversions is down by 20 dB and may be an unreliable observation in low SNR data.

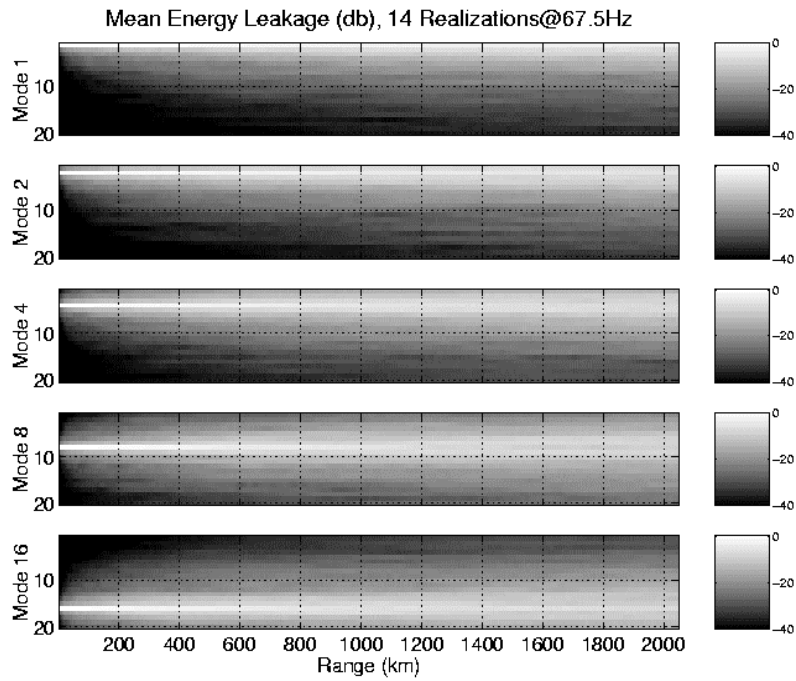


Figure 1 Model leakage vs. range for starting modes 1, 2, 4, 8 and 16

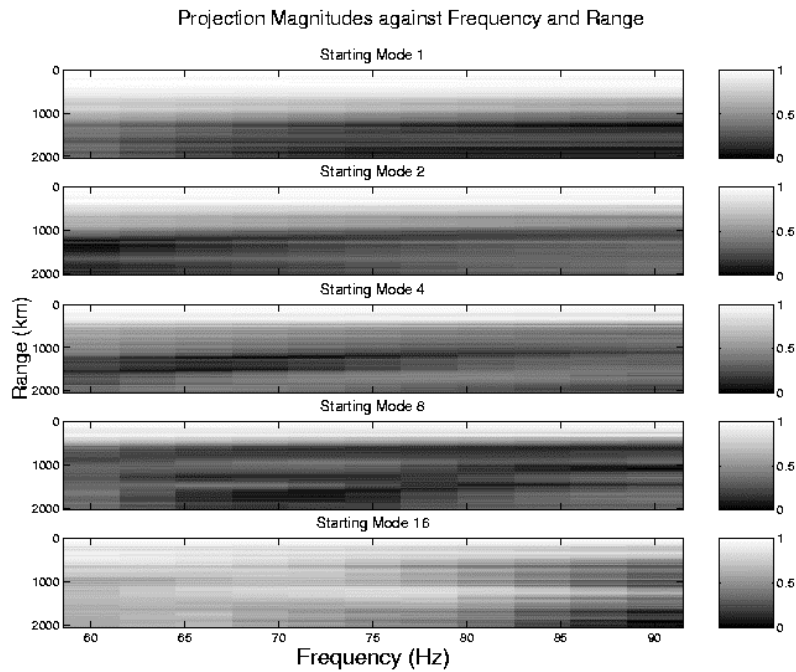


Figure 2: Model projection vs. frequency and range for modes 1, 2, 4, 8 and 16

RELATED PROJECTS

1. Acoustic Observatory Working Group: The objective of the project is to prepare a briefing for ONR, DARPA, and N87 on the issues and design of an ocean acoustic observatory and its use for determining to limits of passive sonar systems.
2. Matched Field Processing for Active and Passive Sonar in Shallow Water: This is in an ONR Code 321 project for the development of matched field processing algorithms in the shallow water.
3. Advisory Committee for the Status of ONR Ocean Acoustics: This was the advisory committee for the UW-APL report assessing the health of ocean acoustics research at ONR.
4. Transarctic Propagation (TAP) experiment: This project was sponsored by ONR 322 on acoustic thermometry across the Arctic Ocean. The data analysis concerned several issues on modal coherence.

REFERENCES

1. L. B. Dozier and F. D. Tappert, "Statistics of normal mode amplitudes in a random ocean. I. Theory," *J. Acoust. Soc. Am.*, vol. (63(2), pps. 353 - 365, (February 1978)
2. L. B. Dozier and F. D. Tappert, "Statistics of normal mode amplitudes in a random ocean. II. Computations," *J. Acoust. Soc. Am.*, vol. 64(2), pps. 533 - 547, (August 1978)
3. J. A. Colosi and S. M. Flatte, "Mode coupling by internal waves for multimegameter acoustic propagation in the ocean," *J. Acoust. Soc. Am.* vol. 100(6), pps. 3607 - 3620, (December 1996)

PUBLICATIONS

1. B. Baggeroer and E. K. Scheer, "Modal leakage in a range dependent environment," *Conference Proceedings of the 1998 International Conference on Acoustics*, Seattle, WA (June 1998)
2. P. N. Mikhalevsky, A. Gavrilov and A. B. Baggeroer, "The Transarctic propagation (TAP) experiment," accepted for publication October 1998, *IEEE Journal of Oceanic Engineering*, (special issue on long range propagation)